Energy Conservation on-board Ships through Enhancing Energy Management

B. Sabarish, M. Cheralathan

Abstract : Fuel consumption on-board ships is a major concern for generating electricity for Heating, Ventilation and Air conditioning systems (HVAC), Operating machineries and equipment, lighting and other electrical utilities. The conventional fuel supply also slowly reducing and become completely vanish in the years to come. The alternate and most appropriate system for the cooling operation and efficient method of operating electrical utilities in ships is essential so as to reduce the electricity consumption as well solution to economic crisis and eradicating emission problems. Fuel consumption can be reduced by optimising the use and exploitation of machinery and equipment systems. To minimise fuel consumption, fuel cost and emission from machineries, significant viable energy efficiency measures should be considered. Major focus on this study is to provide effective ways for reducing on-board power demand which are Thermal Energy Storage for air conditioning applications, Automated Power Management Systems and conversion of existing conventional system with the replacement of energy efficient systems or components. In this study also addressed the preliminary indicators for identifying niche areas for reducing energy consumption and mitigating CO_2 emission in on-board ships.

Keywords: Energy management, energy conservation, energy efficiency, HVAC system, on-board ships

I. INTRODUCTION

The typical Power generation system onboard ships constitutes two systems. First one is the main propulsion which is catered by large capacity diesel engine and second one is the small capacity diesel generators for catering all electrical & electronic utilities which include HVAC systems, refrigeration systems, auxiliary machineries, lighting, Navigational equipment, communication sets and galley & laundry machineries etc. The combustion product of any diesel engine produces a large amount of pollutants like Sulphur oxides and Nitrous oxides. To address the emission issues, strict laws and regulations have been imposed both globally and regionally. The ship emission has been regularly monitored and regulated by the International Maritime Organisation (IMO) which is the major global organisation. The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main internal convention covering prevention of pollution of the marine environment by ships from operational accidental causes [1]. As per IMO report [2], shipping contributed 3.3 % of global CO_2 emission. If no further actions are taken, it is estimated that shipping greenhouse emissions could increase by up to 250 % by 2050. Besides, with decreasing availability and increasing prices of fossil fuels, the economic concern rises. Hence, on-board fuel consumption reduction and emission become priority research objectives in marine applications. HVAC system is an essential and mandatory machineries to maintain thermal comfort inside the ship for the crews in ship habitability and hygiene as well to protect the precious electrical/electronic equipment, main propulsion & gun/ missile control systems from malfunctioning/inaccuracies and to perform their intended functions. The HVAC system is a second to propulsion for consuming energy produced by diesel generators on a conventional ships and can account for 40-50% fuel consumption. The consumption of fuel is around 500-5000 tonnes of fuel each year depending upon the class of ship and operations it performs. The mismatch between cooling demand and fuel shortage is a major issue in marine applications during extreme climate conditions. The demand and supply mismatch presents new challenges and uncertainties to electrical utilities. Hence, HVAC systems must be designed to have sufficient flexibility for load shifting and energy usage control in order to achieve the most economical operation. Worldwide, many researchers are working in the research area of advanced HVAC system to build and develop an efficient, economical and eco-friendly system. One of the latest ships built by M/s Goa Shipyard Limited for the Indian Coast Guard service is considered in the present study. A typical energy flow diagram of a Ship diesel generator is shown in Fig.1 below.

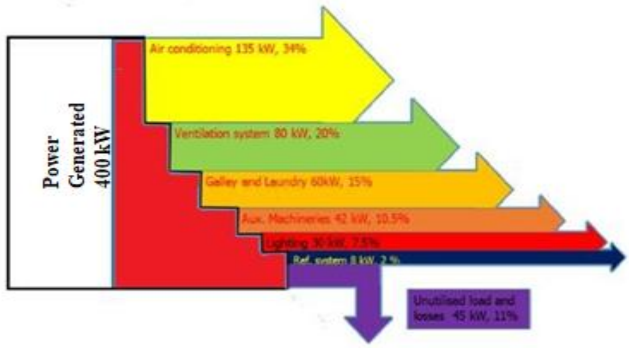

Fig. 1. Energy consumption pattern on-board ship

II. SYSTEM DESCRIPTION

Vapour Compression systems are used on-board because of its high efficiency and co-efficient of performance compared to vapour absorption systems. Change of state is always associated with a latent heat of phase change and is absorbed from the surroundings. This is the principle behind vapour compression systems. The vapour used is cycled between liquid and gaseous phases. The liquid to gas phase change absorbs heat from the surrounding (the evaporator)

Revised Manuscript Received on April 30, 2019.

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and vapour to liquid change needs work to be done, and is supplied by a compressor. Thus, in a vapour compression system, a compressor which Compresses the refrigerant vapour into high pressure vapour, a condenser which cools the sub cooled liquid vapour into liquid phase, a thermostatic expansion valve (TEV) or a capillary tube, which regulates the flow of liquid and an evaporator in which the liquid refrigerant absorbs the heat and forms into saturated vapour. The vapour which comes out from the evaporator coils is not really saturated, but superheated. The compression discharge line will be always pressurized compared to the suction side, and thus is called High Pressure side. Usually the line till the TEV is called H.P side. HP pressure refers to the pressure in this side, and is read by a gauge fixed in the compressor discharge. The compressor suction side from TEV to the suction port is at a Low Pressure, compared to the H.P side and this called L.P. evaporator pressure is always referred as

L.P pressure, and is of very much importance in the refrigeration system.The schematic layout of typical ships air conditioning system is as shown in the Fig 2.

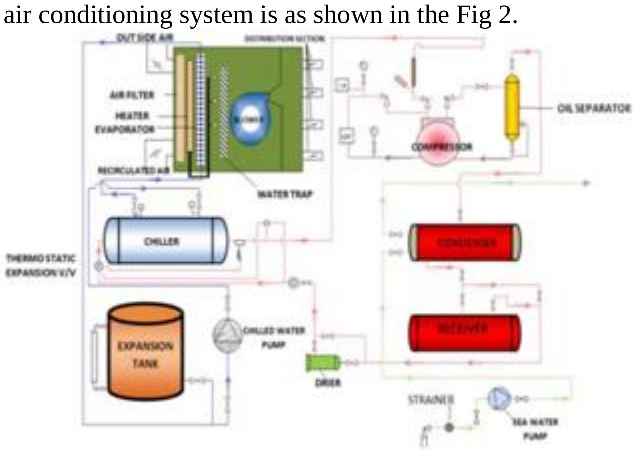


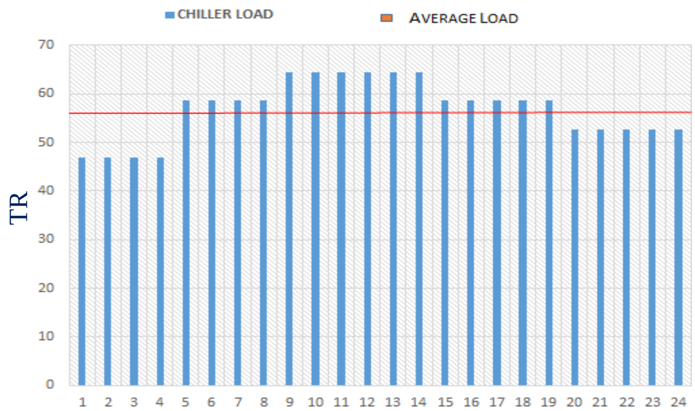
Fig. 2. Schematic layout of Ships Air Conditioning system **The system consists of Centralized Chilled water** plant and compartments being served by 3 nos. central air handling unit. Three nos. chilled water AC plant each of cooling capacity 70TR are provided as one in operation and others as backup. The configuration may also change with two plants working and one backup depending upon the climatic conditions. Each plant consists of one each Semi hermetic compact screw compressor, sea water cooled shell and tube condenser, plate type evaporator, complete with required valves and controls. All enclosed accommodation spaces will be air conditioning by means of 3 nos AHUs. Fresh air shall be mixed with respective recirculation air before entering the respective Air handling units (AHUs). Chilled water through respective AHUs shall be circulated through chilled water pump and sea water through condenser by sea water pump. Floor mounted AHU for single duct system, in marine design, made of aluminium frame with stainless steel double walled panels of 43 ± 2mm thick and inside insulated by 40 ± 2 kg/m3 pre filter type thickness 50 mm. Air intake and mixing section is fitted with fresh and return air manual operated dampers. Filter section is fitted with removable and cleanable filters and cooling section with cooling coil for chilled water. Fan section is fitted with V- belt driven centrifugal fan of static pressure 180 mm wg with fan speed of 2045 rpm. The technical data of the AC plant is given in Table 1.

Table 1 Technical Data of the AC Plant

Description	Specification
Cooling capacity	70 TR /each
Quantity	3 nos.
Chilled water Out temp.	7.0 ± 1 °C
Chilled water In temp.	13.0 ± 1 °C
Evaporator temp.	3 °C
Condensing temp.	45 °C
Refrigerant	R 134a
Lubrication oil	ISO 68
Power Supply	415 V, 3 Phase, 50 Hz
Ambient Temperature	40 °C (DBT) and 30 °C (WBT)
Inside condition	25 °C (DBT) (22.5 °C Effective temp & 60 % RH)
Sea water temp	32 °C (maximum)

Fig 3 shows the hourly cooling load profile from 0100hrs to 2400hrs with mass flow of chilled water 9.8 kg/sec with reference to outdoor temperature. The cooling load varies from 46.8 TR to maximum of 64.5 TR. The peak load of

64.5 TR was observed between 0900 hrs to 1400 hrs.



Time of day (Hour) Fig. 3. Cooling load profile

III. EFFICIENT WAYS OF ENERGY MANAGEMENT ON-BOARD SHIPS

A. Utilisation of Cold Thermal Energy Storage

Main use of Thermal energy Storage is to overcome the mismatch between energy generation and energy use. The implementation of CTES technologies in marine HVAC application will certainly mitigate CO_2 emission and bring cost effective thermal management [4]. The outcome will increase the efficiency of the system and enhance the use of renewable energies. The CTES system using Phase Change Materials for latent heat storage is viable solution and most efficient method in reducing the fuel consumption on-board power generation thereby reducing the electricity consumption and greenhouse emissions.

B. Automated Power Management Systems

The implementation of Automated Power Management System ensures optimal utilisation of power and

avoid wastage of energy. The system automatically determines the number of generators should be in operation at any time. The automation system may also start/stop certain pre-determined equipment to keep the electrical load manageable by number of generators in operation. APMS is a proven technology for efficient control of operation of equipment since the 'human error' factor is not involved.

C. Conversion of Existing Conventional Systems

(i) Energy Efficient Motors

The replacement of normal motors with energy efficient motors will reduce the losses experienced by conventional motors (iron loss, stator and rotor 12R loss, frictional loss etc.) and thus in saving power and improving efficiency. These energy efficient motors provide better performance even at low temperature and the starting torque required is lesser than the conventional type of motors.

(ii) Energy Efficient Transformers

Energy efficient transformer has a major advantage of reducing the energy loss over conventional transformer by 70%. This transformer uses amorphous material and metallic glass alloy for the core. Other significant advantage of energy efficient transformers is that it provides high efficiency even at low loads. At an average of 35 % load, approximately 98

% efficiency can be achieved.

(iii) Installation of Shaft Generators

Installation of efficient shaft generators that can act as an engine as well as diesel alternator will reduce the energy consumption of the ships as one machine will meet the requirement of engine and diesel alternators.

(iv) Tapping of photo voltaic (PV) or solar power for usage on-board

The solar energy is available in abundance and effective tapping of the same for meeting the energy requirement is the need of hour. The solar power may be stored in batteries through solar grids that will be placed on the ship to absorb the solar radiations. The energy thus stored in the batteries may be used at any given instance at any time of the day. The tapping of solar energy is the easiest and cost effective technique to meet the energy requirement of ships. Though the storage and increasing the efficiency of the PV cells is still a challenge and lots of efforts are required to be put in to tap this huge source of energy.

IV. DISCUSSION OF RESULTS

The power distribution for the entire machinery and equipment onboard Ship has been analysed and HVAC consumes around 35-40% of total power generated. By selecting suitable Phase Change Material for the Thermal Energy Storage, the energy can be stored from the Air conditioning system during the period between 2000hrs to 0600 hrs in a day so as to reduce the power consumed by the compressor significantly [Fig.3]. The energy loss during storing and retrieving from the thermal storage system can also be reduced by proper insulation. The study carried out in this paper is unique in nature and will be very useful when installed onboard ships after further research work.

V. CONCLUSION

This paper is focused on the distribution of power to various systems and the functioning of air conditioning system installed on-board ship in detail. The major power consumed by HVAC system can be drastically reduced by suitable Cold Thermal Energy Storage systems using Phase Change Materials. Efficient energy conservation on-board ships by various methods has also been discussed in this paper.

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B Sabarish is a Commandant, Regional Technical Officer (Engg) working in Indian Coast Guard at RHQ(East) Chennai. He completed his Masters in Mechanical Engineering (Marine) from Defence Institute of Advanced Technology, Deemed University, Pune during the year 2013. He has been pursuing his Ph.D., degree from SRM Institute of Science and Technology, Kattangulathur, Chennai from 2018. He has about 26 years of professional experience in the marine field, and appointed as Engineering Officer in different class of Ships and Units of Coast Guard at various levels. He has published 02 research papers in International Journals and adjudged best paper award for the paper presented in CORCON International conference. He is a Member of Institution of Engineers, India. His present area of research is Thermal Energy Storage in Heating and Cooling load applications.

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